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SELECTION OF CONSTRUCTION ORGANISATION MODEL TAKING INTO ACCOUNT TOTAL CONSUMPTION OF ENERGY IN CONSTRUCTION PROCESS

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Abstract. The model of construction organization alternatives, taking into account total energy consumption for a construction process has been developed in the paper. An energy estimating procedure to identify the imbedded energy content in-process of construction and of in-site end building has been described. The procedure has been applied to a construction process to identify major areas of energy use and opportunities for better energy using. The model includes applying game theory. A case study – selection of construction strategy of blockhouse flats, which are presented.

Keywords: construction, strategy, multi-criteria, energy consumption, game theory.

Introduction

The crisis around the world has contributed to the saving of resources in all range of industries. Therefore, issue of resource-saving in construction is also relevant. Prices of energy are rising. Builders, construction companies and prospective customers look for the construction with low use of energy, and need to optimize the construction works. This problem is analised by many researchers:

- Sorrentino *et al.* (2010) presented the model for simulation and optimal energy management;
- Radhi *et al.* (2009) investigated impact of energy regulations on building comfort;
- Juodis *et al.* (2009) investigated inherent variability of heat consumption in residential buildings.

Assessment of construction strategy taking in to account consumption of energy

Many authors investigated strategies for energy-efficient construction (Gu *et al.* 2009; Díaz *et al.* 2009; Lee and Lee 2009; Huang *et al.* 2009; Steemers and Yun 2009; Distefano and Belenky 2009):

- Gu *et al.* (2009) investigated strategies for energy-efficient housing developments and combined them with Swedish experiences (from an architect's perspective);
- Díaz *et al.* (2009) explored energy saving scenarios for on-demand pressurised irrigation networks;
- Lee and Lee (2009) investigated the performance of building energy management benchmarking using data envelopment analysis;
- Huang *et al.* (2009) presented energy consumption balanced WSN routing protocol;
- Steemers and Yun (2009) investigated household energy consumption;
- Distefano and Belenky (2009) presented life-cycle analysis of energy and greenhouse gas emissions from anaerobic biodegradation of municipal solid waste.

The strategies can be selected individually for each case, considering overall building envelope, building geometry, number of floors, orientation and etc. A strategy selection is impacted by new technologies, worksite conditions, building construction characteristics, company and the available resources. It is impacted by handled machinery and equipment base, experience, available staff and etc.

For the strategy selection of construction process taking into account energy consumption problem can be solved considering two different conditions:

- ***Technology*** – the choice of new energy-efficient construction technologies;
- ***Organization*** – reduce amounts of electricity-intensive in construction process and etc.

The problem of energy consumption in construction process is investigated and discussed by many authors:

- Rowings *et al.* (1984) investigated energy use in construction;
- Ma *et al.* (2009) described modelling energy consumption behaviours and changes in energy intensity;
- Zhu *et al.* (2009) investigated dynamic characteristics and energy performance of buildings in using phase changing construction materials;
- Kalogirou (2009) investigation deals with energy applications in buildings;
- Su (2009) investigated impact on energy efficiency for a house with temporary heating and winter daytime cross ventilation;
- Magnier and Haghighat (2010) assessed building designs by applying multi-objective optimization;
- Zheng *et al.* (2010) evaluated energy conservation in building.

Research methodology

For the strategy problem solution was selected the game theory mathematical method. Application of game theory for multiple criteria decision analysis in construction can be found in Peldschus *et al.* (1983, 2008b). Peldschus (1986, 2007a, b, 2009) analysed the effectiveness of assessments in multi-criteria decision. Multi-criteria optimisation system for decision making in construction design and management was proposed by Turskis *et al.* (2009). The methodology that was applied in this study for problem solution is the game theory. The proposed process provides a logical and scientific foundation in which the values of decision makers and stakeholders can be integrated.

The model of construction strategy selection taking into account energy consumption by applying game theory is presented in Fig 1.

With respect to construction, property development and management the applications of game theory was applied for different problem solution: Zavadskas *et al.* (2003) presented the software for multiple criteria evaluation; Zavadskas *et al.* (2004) solved problems of construction technology and management; Peldschus and Zavadskas (2005) investigated fuzzy matrix game in construction; Homburg and Scherpereel (2008) developed analysis for performance measurement; Ginevičius and Krivka (2008) presented application of game theory for duopoly market analysis; Peldschus (2008a) analysed game theory application experience in construction management; Podvezko (2008) developed the problem in building technology and management; Tamošaitienė *et al.* (2008) proposed the model of contractor selection taking into account different risk level; Zavadskas *et al.* (2008) developed the multi-criteria optimization software LEVI-4.0; Gu *et al.* (2009) analysed Chinese strategies for energy-efficient housing developments from an architect's perspective.

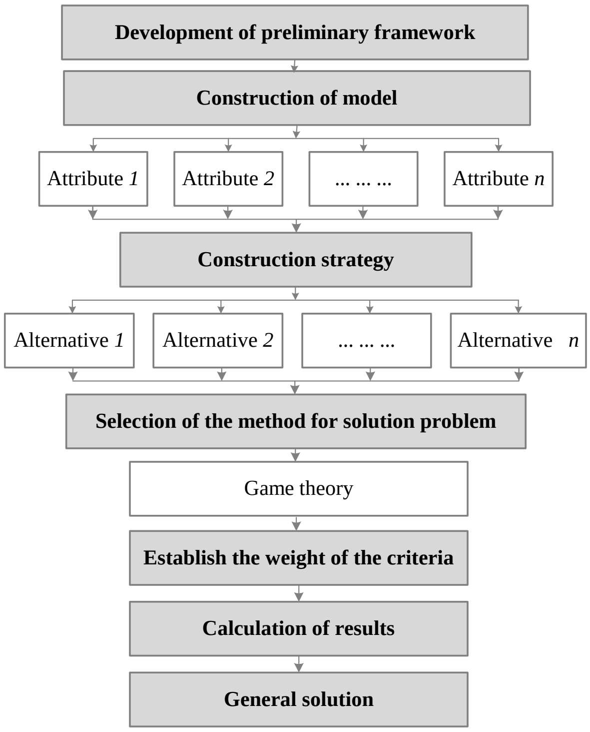


Fig 1. Construction organization selection of taking into account energy consumption

The Laplace rule was selected for the best construction strategy selection (Peldschus 1986):

$$S_1^* = \left\{ S_{1i} / S_{1i} \in S_1 \cap \max_i \left(\frac{1}{n} \sum_{j=1}^{n} a_{ij} \right) \right\}. \quad (1)$$

To reduce energy consumption and price of the construction energy cost it should be used efficient in construction process. This can be achieved by selecting the most rational construction strategy. In general, energy consumption at the construction site is calculated on the basis of:

- Requirement of energy consumption *E*;
- Number of illuminators and floodlights is calculated by proper lighting of intensity *P* profiles.

Also the numbers of the floodlight *n* must be determined (Zavadskas *et al.* 2009).

Zavadskas *et al.* (2009) presented the methodology of construction energy consumption assessment. Worksite is supplying with 380/220 V electricity power (380 V electrical motors and other electrical power equipment, 220 V – for lighting, electric tools). Temporary networks are designed to ensure a constant supply, so that the pools of all consumers are minimized.

The requirement of energy consumption *E* of construction processes is calculated as follows (Zavadskas *et al.* 2009):

$$E = a\left(\frac{k_g \sum E_g}{\cos\varphi_1} + \frac{k_t \sum E_t}{\cos\varphi_2} + k_a \sum E_v + k_i \sum E_i\right), \quad (2)$$

where a – network power losing ratio, E_g – total engine power for the construction material manufacture, kW; E_t – total energy for the construction technology, power kW; E_v – total energy power for the inside lighting network; E_i – total energy power outside lighting network, kW; k_g, k_t, k_a, k_i – the ratio of loading, rating of number contemporaneously working consumer; $\cos\varphi_1$, $\cos\varphi_2$ – the ratio of power.

The number of illuminator and floodlight is calculated according to lighting of intensity P (Zavadskas *et al.* 2009):

$$P = 0.25 E_a \cdot k, \quad (3)$$

where P – comparative lightning intensity of the work place, Lx; E_a – lightning standard, Lx (territory – 2 Lx, security lightning – 0.5 Lx, emergency of the work place – 1–3 Lx; emergency evacuation accident – 0.5 Lx); k ratio of the reserve ($k = 1.5$).

The number of the floodlight n is determined as follows (Zavadskas *et al.* 2009):

$$n = \frac{P \cdot S}{P_1}, \quad (4)$$

where S – the area of the lightning territory, m^2; P_1 – power of the floodlight, W.

Engine power and electricity needs are taken into account by the special status and rates of load and power factor – from manuals.

Case study: selection of construction strategy taking into account total consumption of energy in construction site

The example deals with selecting strategy of the building construction in Vilnius. The area of the construction site is 3500 m^2. The building's usable area is 850 m^2, building height – 20 m.

The construction strategies were formulated by applying different organization models of construction processes. Each construction organization model was described by parameters of energy consumption:

- total engine power for the construction material manufacturing – E_g;
- total energy for the construction technology – E_t;
- total energy power for the inside lighting network – E_v;
- total energy power for the outside lighting network – E_i;
- the number illuminators and floodlights is calculated by proper lighting of intensity – P;
- numbers of the floodlight – n.

The problem solution process (feasible alternatives, initial decision-making matrix and normalised decision-making matrix) is presented in the Table 1. The value of E, P and n was calculated applying formulas 2, 3 and 4 (Zavadskas *et al.* 2009). Optimization directions of all selected criteria are the same – minimum.

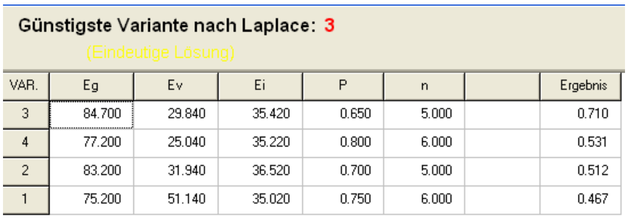
The values of normalized decision-making matrix are calculated by applying linear normalization method (Zavadskas and Turskis 2008):

$$\bar{x}_{ij} = \frac{\max_i x_{ij} - x_{ij}}{\max_i x_{ij} - \min_i x_{ij}}, \quad \bar{x}_{ij} = \frac{x_{ij} - \min_i x_{ij}}{\max_i x_{ij} - \min_i x_{ij}}. \quad (5)$$

Table 1. Initial decision-making and normalized decision-making matrixes

	Alter-native	Criteria				
		E			P	n
		E_g	E_v	E_i		
Initial decision-making matrix	A_1	75.20	51.14	35.02	0.75	6
	A_2	83.20	31.94	36.52	0.70	5
	A_3	84.70	29.84	35.42	0.65	5
	A_4	77.20	25.04	35.22	0.80	6
Normalized decision-making matrix	A_1	1.00	0.00	1.00	0.33	0
	A_2	0.16	0.74	0.00	0.67	1
	A_3	0.00	0.82	0.73	1.00	1
	A_4	0.79	1.00	0.87	0.00	0

The problem was solved by applying the software for multi-criteria optimization LEVI-3.0. Problem's solution results are presented in the Fig 2.


Günstigste Variante nach Laplace: 3
(Eindeutige Lösung)

VAR.	Eg	Ev	Ei	P	n		Ergebnis
3	84.700	29.840	35.420	0.650	5.000		0.710
4	77.200	25.040	35.220	0.800	6.000		0.531
2	83.200	31.940	36.520	0.700	5.000		0.512
1	75.200	51.140	35.020	0.750	6.000		0.467

Fig 2. Solution results

The feasible alternatives rank as follows: $A_3 \succ A_4 \succ A_2 \succ A_1$.

It can be stated that the best alternative is the third alternative with the result 0.710, and the worst alternative is the first alternative with the result 0.467.

Conclusion

In the paper is presented newly developed model for selection of construction strategy taking into account total consumption of energy in construction processes. For this reason is determined set of criteria, selected decision making method – game theory (Laplace rule) and presented practical example, which was applied in practice. The proposed model allows to analysers and decision-makers to select the best alternative. The feasible alternatives can be ranked according too.

References

Díaz, J. A. R.; Luque, R. L.; Cobo, M. T. C.; Montesinos, P.; Poyato, E. C. 2009. Exploring energy saving scenarios for on-demand pressurised irrigation networks, *Biosystems Engineering* 104(4): 552–561. doi:10.1016/j.biosystemseng.2009.09.001

Distefano, T. D.; Belenky, L. G. 2009. Life-cycle analysis of energy and greenhouse gas emissions from anaerobic biodegradation of municipal solid waste, *Journal of Environmental Engineering* 135(11): 1097–1105. doi:10.1061/(ASCE)EE.1943-7870.0000098

Ginevičius, R.; Krivka, A. 2008. Application of game theory for duopoly market analysis, *Journal of Business Economics and Management* 9(3): 207–217.

doi:10.3846/1611-1699.2008.9.207-217

Gu, Z.; Vestbro, D. U.; Wennersten, R.; Assefa, G. 2009. A study of Chinese strategies for energy-efficient housing developments from an architect's perspective combined with Swedish experiences and game theory, *Civil Engineering and Environmental Systems* 26(4): 323–338. doi:10.1080/10286600802151853

Huang, F.; Jin, X.-Y.; Zhang, Y.; Tang, J. 2009. Energy consumption balanced WSN routing protocol based on GASA, *Chinese Journal of Sensors and Actuators* 22(4): 586–592.

Homburg, C.; Scherpereel, P. 2008. How should the cost of joint risk capital be allocated for performance measurement? *European Journal of Operational Research* 187(1): 294–312. doi:10.1016/j.ejor.2007.03.020

Juodis, E.; Jaraminiene, E.; Dudkiewicz, E. 2009. Inherent variability of heat consumption in residential buildings, *Energy and Buildings* 41(11): 1188–1194. doi:10.1016/j.enbuild.2009.06.007

Kalogirou, S. A. 2009. Artificial neural networks and genetic algorithms in energy applications in buildings, *Advances in Building Energy Research* 3(1): 83–120. doi:10.3763/aber.2009.0304

Lee, W.-S.; Lee, K.-P. 2009. Benchmarking the performance of building energy management using data envelopment analysis, *Applied Thermal Engineering* 29(16): 3269–3273. doi:10.1016/j.applthermaleng.2008.02.034

Ma, H.; Oxley, L.; Gibson, J.; Kim, B. 2009. Modeling China's energy consumption behavior and changes in energy intensity, *Environmental Modelling and Software* 24(11): 1293–1301. doi:10.1016/j.envsoft.2009.04.011

Magnier, L.; Haghighat, F. 2010. Multiobjective optimization of building design using TRNSYS simulations, genetic algorithm, and Artificial Neural Network, *Building and Environment* 45(3): 739–746. doi:10.1016/j.buildenv.2009.08.016

Peldschus, F. 1986. *Zur Anwendung der Theorie der Spiele für Aufgaben der Bautechnologie*. Diss. B. Technologie. Technische Hochschule Leipzig (in German).

Peldschus, F. 2007a. The effectiveness of assessments in multi-criteria decision, *International Journal Management and Decision Making* 8(2/3): 193–200.

Peldschus, F. 2007b. Games-theory solutions in construction operation. In Modern Building Materials Structures and Techniques, in M. J. Skibniewski P. Vainiunas E. K. Zavadskas (eds.), in *The 9th International Conference May 16–18 2007. Vilnius, Lithuania. Selected Papers*: 348–353.

Peldschus, F. 2008a. Experience of the game theory application in construction management, *Technological and Economic Development of Economy* 14(4): 531–545. doi:10.3846/1392-8619.2008.14.531-545

Peldschus, F. 2008b. Multi-attribute decision in construction, *Transformations in Business and Economics* 7(2): 163–165.

Peldschus, F. 2009. The analysis of the quality of the results obtained with the methods of multi-criteria decisions, *Technological and Economic Development of Economy* 15(4): 580–592. doi:10.3846/1392-8619.2009.15.580-592

Peldschus, F.; Vaigauskas, E.; Zavadskas, E. K. 1983. Technologische Entscheidungen bei der Berücksichtigung mehrerer Ziehle, *Bauplanung–Bautechnik* 37(4): 173–175.

Peldschus, F.; Zavadskas, E. K. 2005. Fuzzy matrix games multi-criteria model for decision-making in engineering, *Informatica* 16(1): 107–120.

Podvezko, V. 2008. Game theory in building technology and management, *Journal of Business Economics and Management* 9(3): 237–239. doi:10.3846/1611-1699.2008.9.237-239

Radhi, H.; Eltrapolsi, A.; Sharples, S. 2009. Will energy regulations in the Gulf States make buildings more comfortable – A scoping study of residential buildings, *Applied Energy* 86(12): 2531–2539. doi:10.1016/j.apenergy.2009.04.003

Rowings, Jr.; James, E.; Walker, Jr.; Richard, O. 1984. Construction energy use, *Journal of Construction Engineering and Management* 110(4): 447–458. doi:10.1061/(ASCE)0733-9364(1984)110:4(447)

Steemers, K.; Yun, G. Y. 2009. Household energy consumption: A study of the role of occupants, *Building Research and Information* 37(5-6): 625–637. doi:10.1080/09613210903186661

Su, B. 2009. Energy efficiency design for a house with temporary heating and winter daytime cross ventilation. *International Journal of Ventilation,* 8(2): 109–116.

Sorrentino, M.; Rizzo, G.; Genova, F.; Gaspardone, M. 2010. A model for simulation and optimal energy management of Telecom switching plants, *Applied Energy* 87(1): 259–267. doi:10.1016/j.apenergy.2009.06.019

Tamošaitienė, J.; Turskis, Z.; Zavadskas, E. K. 2008. Modelling of contractor selection taking into account different risk level, In 25th International Symposium on Automation and Robotics in Construction ISARC-2008 in E. K. Zavadskas, A. Kaklauskas, M. J. Skibniewski (eds.), in *The 25th International Symposium on Automation and Robotics in Construction, Jun 26-29, 2008 Vilnius, Lithuania, Selected Papers:* 676–681.

Turskis, Z.; Zavadskas, E. K.; Peldschus, F. 2009. Multi-criteria optimization system for decision making in construction design and management, *Inzinerine Ekonomika-Engineering Economics* 1(61): 7–17.

Zavadskas, E. K.; Turskis, Z. 2008. A new logarithmic normalization method in games theory, *Informatica* 19(2): 303–314.

Zavadskas, E. K.; Peldschus, F.; Turskis, Z. 2008. Multi-criteria optimization software LEVI-4.0 – A tool to support design and management in construction. In 25th International Symposium on Automation and Robotics in Construction ISARC-2008 in E. K. Zavadskas A. Kaklauskas M. J. Skibniewski (eds.), in *The 25th International Symposium on Automation and Robotics in Construction Jun 26-29 2008 Vilnius, Lithuania, Selected Papers*: 731–736.

Zavadskas, E. K.; Peldschus, F.; Ustinovichius, L.; Turskis, Z. 2004. *Game Theory in Building Technology and Management*. Technika, Vilnius (in Lithuanian).

Zavadskas, E. K.; Ustinovichius, L.; Peldschus, F. 2003. Development of software for multiple criteria evaluation, *Informatica* 14(2): 259–272.

Zavadskas, E. K.; Mikšta, P.; Sakalauskas, R.; Šimkus, J. R.; Ustinovičius, U. 2009. *Construction Organization*. Technika, Vilnius (in Lithuanian).

Zheng, G.; Jing, Y.; Huang, H.; Shi, G.; Zhang, X. 2010. Developing a fuzzy analytic hierarchical process model for building energy conservation assessment, *Renewable Energy* 35(1): 78–87. doi:10.1016/j.renene.2009.07.008

Zhu, N.; Ma, Z.; Wang, S. 2009. Dynamic characteristics and energy performance of buildings using phase change materials: A review, *Energy Conversion and Management* 50(12): 3169–3181. doi:10.1016/j.enconman.2009.08.019